2. DESCRIPTION OF DIRECT TESTING

The intent of the direct corrosion testing focuses on a timed study of corrosion under natural SDA environmental conditions of precipitation and soils. The testing consists of burying metal coupons assembled in arrays, then retrieving the coupons after various time intervals ranging from 1 year to as many as 32 years. Corrosion rates are determined from the change in coupon weights over time. Activities associated with the direct corrosion test are being conducted in accordance with appropriate standard practices and guidelines, including, but not limited to, ASTM Methods G 1, G 4, G 15, G 16, G 30, and G 46.

2.1 Test Coupons And Materials

Each coupon array consists of four test coupons each of the following nonradioactive metals: low-carbon steel, Type 304L stainless steel, Type 316L stainless steel, welded Type 316L stainless steel, Inconel 718, Beryllium S200F, Aluminum 6061, Zircaloy-4, and welded Ferralium 255, for a total of 36 coupons in each coupon array.

The selection of test materials is based primarily on a study by Rood and Adler-Flitton (1997), which determined that Types 304/304L and 316/316L stainless steels, Inconel 718, Beryllium S200F, Aluminum 6061, and Zircaloy-4 were appropriate materials to be included in the LTCD Test. The decision was based on the amounts and types of material present at the SDA and on the conclusion that these alloys would become activated after exposure in a neutron flux. Welded Type 316L stainless steel was included to investigate stress-corrosion cracking. Carbon steel was added because of the large underground corrosion database available for this material and because it is used for the disposal liners of the 55-ton scrap casks and for various other disposal containers buried at the SDA. Welded Ferralium 255 (a duplex stainless steel) was also added to the list, as it was the prospective material for high integrity disposal containers that might be used in the future for the disposal of certain wastes.

The corrosion coupons are 3 × 3 × 1/8 in. (see Figures 5 and 6) with a 0.56-in. diameter hole in the center. In general, the coupon surface finish is 120 grit; however, the beryllium coupons, with a 125 RMS[a] finish, have the same surface finish as the beryllium waste disposed of at the SDA.

2.2 Coupon Preparation

The corrosion coupons were obtained from a commercial vendor who has implemented an INEEL-approved quality program. When the coupons arrived at the INEEL, they were handled with tongs or gloved hands. All coupons, except those composed of beryllium, were stamped with a unique INEEL identification number. The brittleness of the beryllium material precludes stamping, so the beryllium supplier identified each coupon uniquely with a chemical etching process. All coupons were measured, cleaned, and pre-weighed at the vendor in accordance with the requirements of ASTM Method G 1. Certification papers for the chemical composition and physical properties of all coupons were archived at the Idaho Nuclear Technology and Engineering Center (INTEC) by the Applied Technology Group. Weight, dimensional measurements, and calculated surface area for all coupons were subjected to independent verification at INTEC and are recorded in controlled laboratory notebooks. Each coupon was individually photographed on a background sheet that contains the coupon number, material, surface area, and weight.

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a. RMS (root mean square). Roughness (R_q) as related to irregularities on a surface from a production process such as machining or grinding calçulated by the root mean square average height over the measured surface area.

Since identification numbers on the individual coupons might degrade during the test, a secondary method of identification was also used. Each coupon has a specific coordinate in the coupon array and is assigned a test identification number based on this placement. An example of the coupon array/corrosion coupon nomenclature is CA01-1-1. The first four digits refer to the coupon array number, the next number refers to the rod number in the array, and the last number refers to the coupon position on that rod. Figure 8 illustrates this nomenclature system. After the corrosion coupons were placed on the coupon arrays, photographs were taken of each array for baseline documentation. A map was made showing the location of each coupon as originally placed on the coupon array.

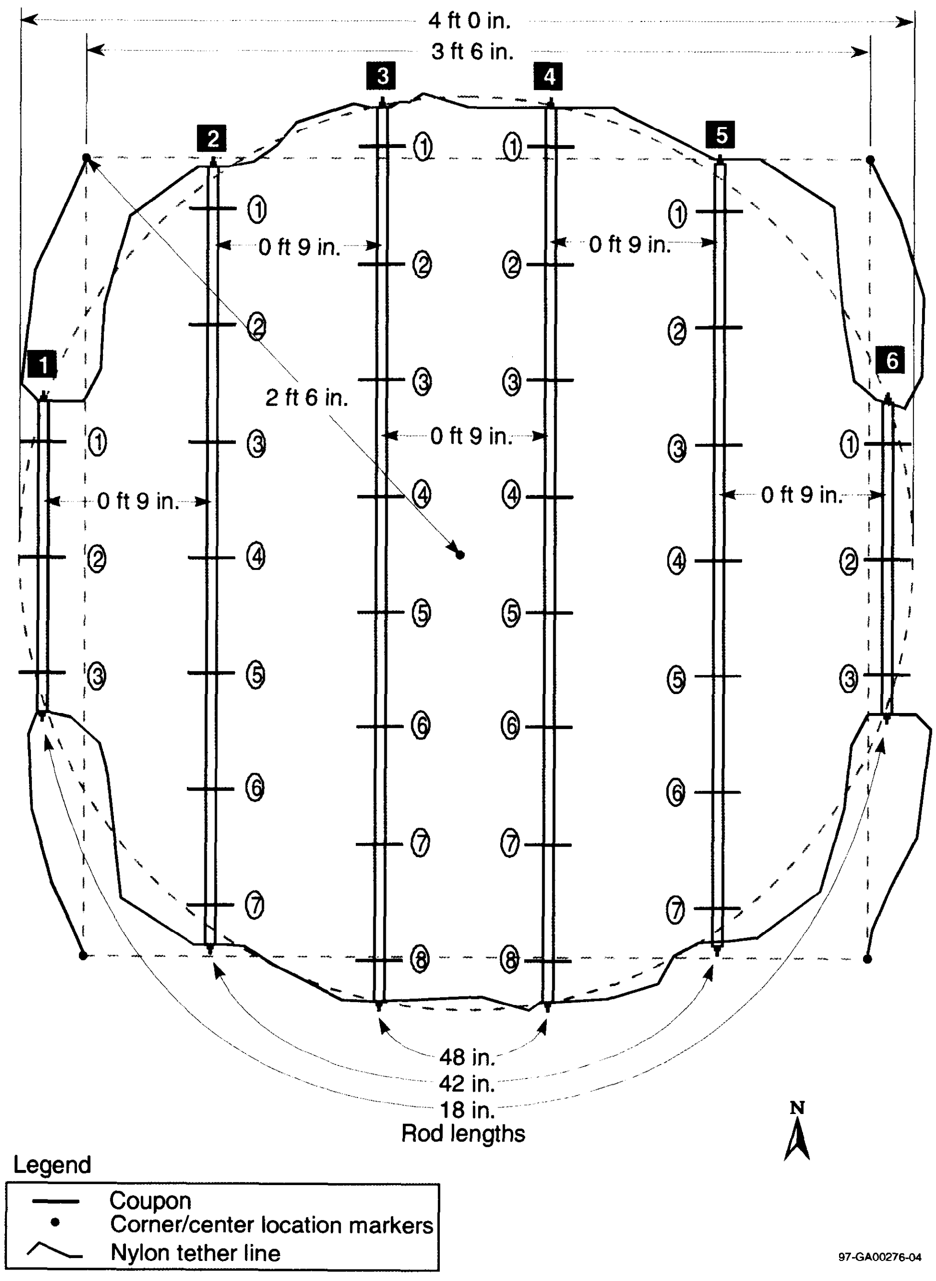

Figure 8. Numbering system for coupons installed in a coupon array.

2.7 Weight Loss Measurement Method

After the coupons were cleaned, they were weighed on the Mettler 163 balance. The weight was subtracted from the original weight of the coupon (before exposure, as recorded in the laboratory notebooks) to calculate the weight loss as a result of corrosion, and the corresponding corrosion rate was calculated. The coupons were also examined with a stereo microscope for localized corrosion and pitting. All samples, including the coupons and metallographic specimens, are archived and stored with the Applied Technology Group.

Weight loss was measured in grams, and the corrosion rate was calculated in MPY. The typical corrosion rate calculation is as follows:

$$\text{Corrosion Rate (MPY)} = \frac{\text{weight loss (g)} \times 393.7}{\text{Density (g/cm}^3) \times \text{Area (cm}^2) \times \text{Time (years)}}$$

The results are presented in Section 3.5.

2.8 Weight-Loss Measurement Uncertainties

The corrosion rate is calculated from a coupon weight loss measurement, so it is important that uncertainties associated with the weight loss measurement be accounted for. This is especially true for the stainless steels and other metals whose corrosion rates are anticipated to be very low. Measurement uncertainties considered for the LTCD test include:

- Statistical errors for the Mettler 163 balance used to weigh the coupons,
- Possible loss of base metal (in addition to corrosion material) to the wash/brush process
- Possible loss of base metal (in addition to corrosion material) to the chemical treatment.

As part of the evaluation of the first year corrosion results, Wilkins et al. (1998) led the investigation of the laboratory balance measurement uncertainty for the range of corrosion coupon weights at 50, 100, and 150 g. Weights of the test coupons range from a low of about 37 g for the beryllium coupons to a high of about 146 g for the Inconel 718 coupons. Balance uncertainties (2σ, 95% confidence level) were found to be $\pm$ 0.4 mg for the 50- and 100-g balance ranges and $\pm$ 0.8 mg for the 150-g balance range.

The measurement uncertainty study also investigated the corrosion coupon weight loss from the wash/brush cleaning. As part of the study, a series of coupon cleaning tests were conducted to collect statistically reliable weight-loss data for typical coupon cleaning processes. The testing consisted of cleaning unexposed archived Type 304L stainless steel, Type 316L stainless steel, and Inconel 718 coupons with the wash/brush process and recording the subsequent weight change. The results apply only to the compositions tested (Type 304L stainless steel, Type 316L stainless steel, and Inconel 718).

The data from the balance uncertainties and cleaning uncertainties were combined to describe the total uncertainties attributed to the minimum detectable corrosion rates. A sufficient number of coupons and cleaning cycles was used to provide statistically significant uncertainties for the processes. The combined cleaning/weighing uncertainties found for the wash/brush cleaning process, at a 95%

confidence level, were ± 0.89 mg for Type 304L stainless steel, ± 0.98 mg for Type 316L stainless steel, and ± 0.92 mg for Inconel 718. Again, these combined results apply only to the three materials that were tested with the wash/brush process, whereas the uncertainties determined for the weighing process apply to all coupon compositions.

Together, the studies show a small uncertainty. For most of the coupons, the very low weight losses measured from 1-year exposure fall within the balance variability and cleaning weight-loss measurements. Whenever the measured weight loss was less than either the balance variability or the combined uncertainty (as applicable), the corrosion rate is listed as "no reportable corrosion." With exception to the Zircoloy-4 coupons, the weight losses from 3-year exposure generally fall outside the balance variability and cleaning weight-loss measurements, so corrosion rates are reported for these results.

The 3-year corrosion coupons composed of beryllium, aluminum, and carbon steel were subjected to a chemical cleaning process in addition to the wash/brush process to remove adhering soil and corrosion products. In accordance with ASTM G 1, a blank (i.e., unexposed) specimen of the same material and heat lot was run through the chemical cleaning process along with the corroded test specimens. The blank specimen was one of the archived coupons. The weight losses measured after cleaning the blank coupons were subtracted from the weight losses of the corresponding corroded coupons to arrive at the weight loss resulting from corrosion, as reported in Section 3.